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research review

OFFICE of AEROSPACE RESEARCH

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field testing the ARL dust separator

1ST LT ROGER A. MILLER, Energetics Research Laboratory, ARL

Dust ingestion by turbine engines is creating quite an operational problem for Armed Forces units in Vietnam. Following a Vietnam inspection tour, a House Armed Services subcommittee of the U.S. Congress reported that engine life had been cut from 1,000-1,600 hours to only 300 hours because of dust ingestion. (1) This is a terrific price to pay to that "hard, red dust" of Vietnam.

As a spin-off of basic research in the areas of internal flow, ARL's Energetics Research Laboratory has been engaged in research on dust separators for military gas turbines for approximately 2 years. By late August 1966, a prototype dust separator had been built and laboratory-tested. This unit is a cluster of sixteen 5" reversed-flow separators, and was designed to handle a mass flow of between 500 and 1,100 cfm. Laboratory testing showed it to obtain separation efficiencies of slightly greater than 90 per cent on standard 0-200μ Arizona road dust. This separation efficiency corresponds to the 4-5μ design cut-off. The laboratory performance parameters of this prototype separator are shown on Figure 1.

In order to evaluate the separator's performance in the field and to compare the results with laboratory results, the unit was mounted on an experimental M-151 jeep vehicle. This jeep was developed, under contract, by the Army Tank Automotive Center, Warren, Michigan. It has a Williams Research Corporation 70-horsepower gas turbine with a flow rate between 500 and 1,100 cfm. The vehicle, as constructed, used a paper-element-type air cleaner which proved to be unsatisfactory. Figure 2 shows the jeep with the original paper filters. The jeep with the ARL experimental separator is shown in Figure 3.

Field testing of the jeep and separator was conducted at the U.S. Army Yuma Proving Grounds, Yuma, Arizona. This was done on a course designed by the Army specifically for the dust-endurance testing of vehicles. The dust course itself is a closed oval about 2½ miles long, and is located atop Melaphyre Mesa approximately 7 miles from the main facilities. The "road" surface on the course varies from a fairly hard top to areas where the dust is between 18" and 24" deep. This dust is so fine that it "splashes" and runs out like water from under the wheels of the vehicles. The last turbine-powered vehicle to be tested on the course ran without an adequate dust separator. It failed on the second lap because of dust ingestion. During the same period that the particle-separator

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testing was being conducted, a standard M-151 jeep (with internal-combustion engine) was undergoing air-filter tests. Running without a lead vehicle to stir up the dust, this jeep could run only for about 15 minutes before the paper filter it was using became clogged.

The experimental vehicle was tested on the dust course according to Yuma Proving Grounds standard operating procedures. Because of the special nature of the separator, however, a lead vehicle was used throughout the testing to stir up a denser cloud. The jeep was instrumented for separator pressure drop, engine-exhaust gas temperature, and engine rpm. Additionally, the separator efficiency was obtained by collecting the dust ejected from the separator and that passed through the separator. The dust-collection system was designed and operated in such a manner that the engine dust-separator system operated under identical conditions with or without the dust-collection system.

Two initial test runs were scheduled without using the dust-collection system. These tests had a twofold purpose: (1) to serve as a "shake-down" on the vehicle, vehicle systems, and dust separator; and (2) to acquaint the Yuma Proving Grounds test drivers with the vehicle. These tests were scheduled for periods of one hour each. Since the second in the series, due to vehicle electrical problems, was only partially completed, an additional third test was run. Nine one-half-hour tests were scheduled with the dust-collection system. However, because of a mechanical failure in the vehicle fuel-control system, only four tests were completed.

The vehicle was run in dust and gravel for slightly more than 150 miles. Seven test

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JACOB SEIDEN
Editor

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From the Editor:

In previous years, the first number of each volume of the Review has appeared in March, and the 12th and last number has appeared in February of the following year. Starting with this issue, our volume year coincides with the calendar year. Thus, Volume V has ended with Number 10, December 1966. Volume VI begins with this, the January 1967 issue.

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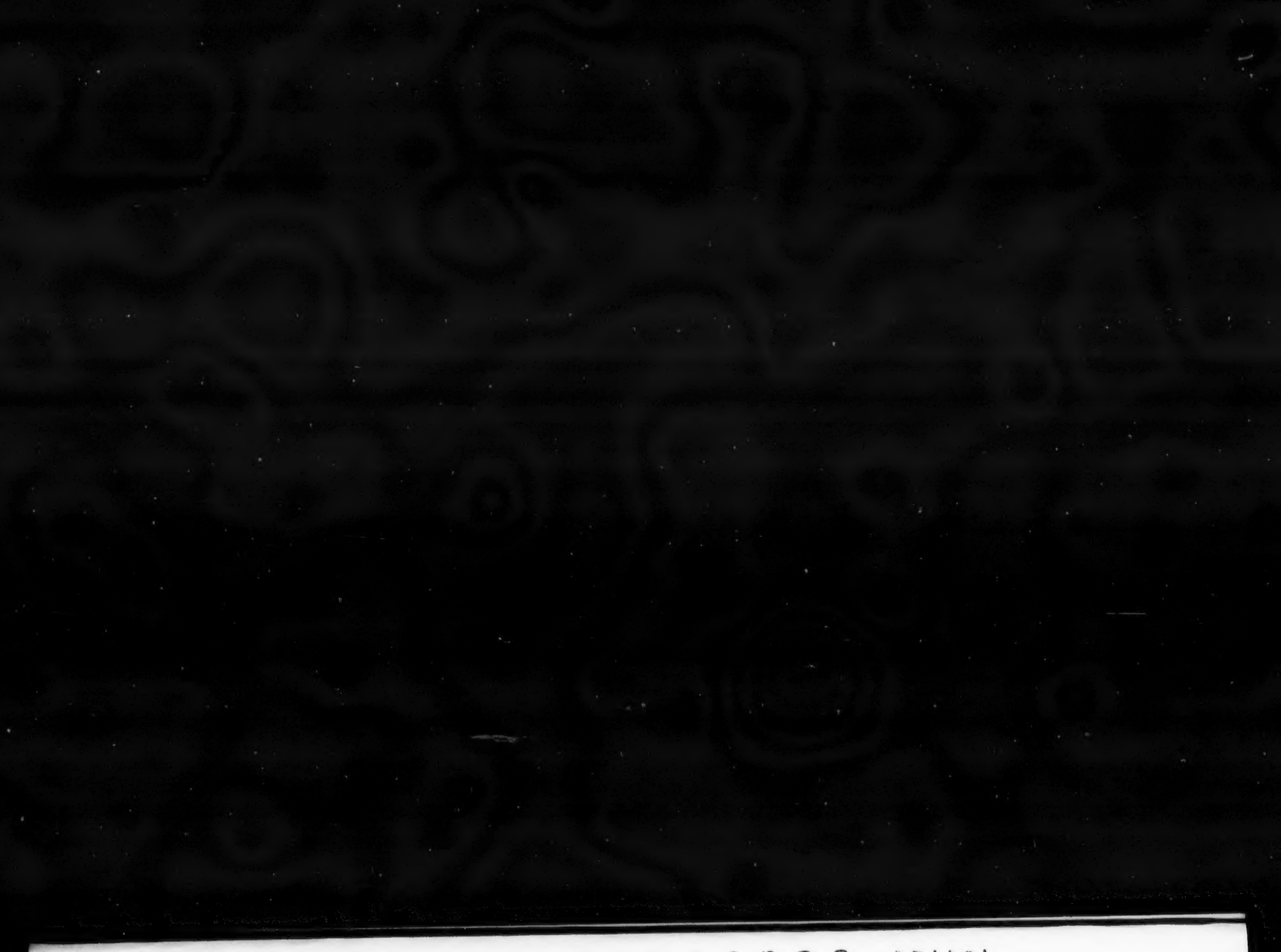

runs were made on the dust course totalling 88.5 miles and 4 hours. Of these 7 runs, separator efficiencies were measured on 4. The results from these tests are summarized in Table I.

Table I Yuma Test Results

Test	Mileage	Time(Min.)	η sep (%)
2a	13.0	32	94.5
2b	14.4	32	94.4
2c	12.2	35	92.5
3a	2.5*	20*	91.7

* Complete zero-zero visibility due to dust on this run.

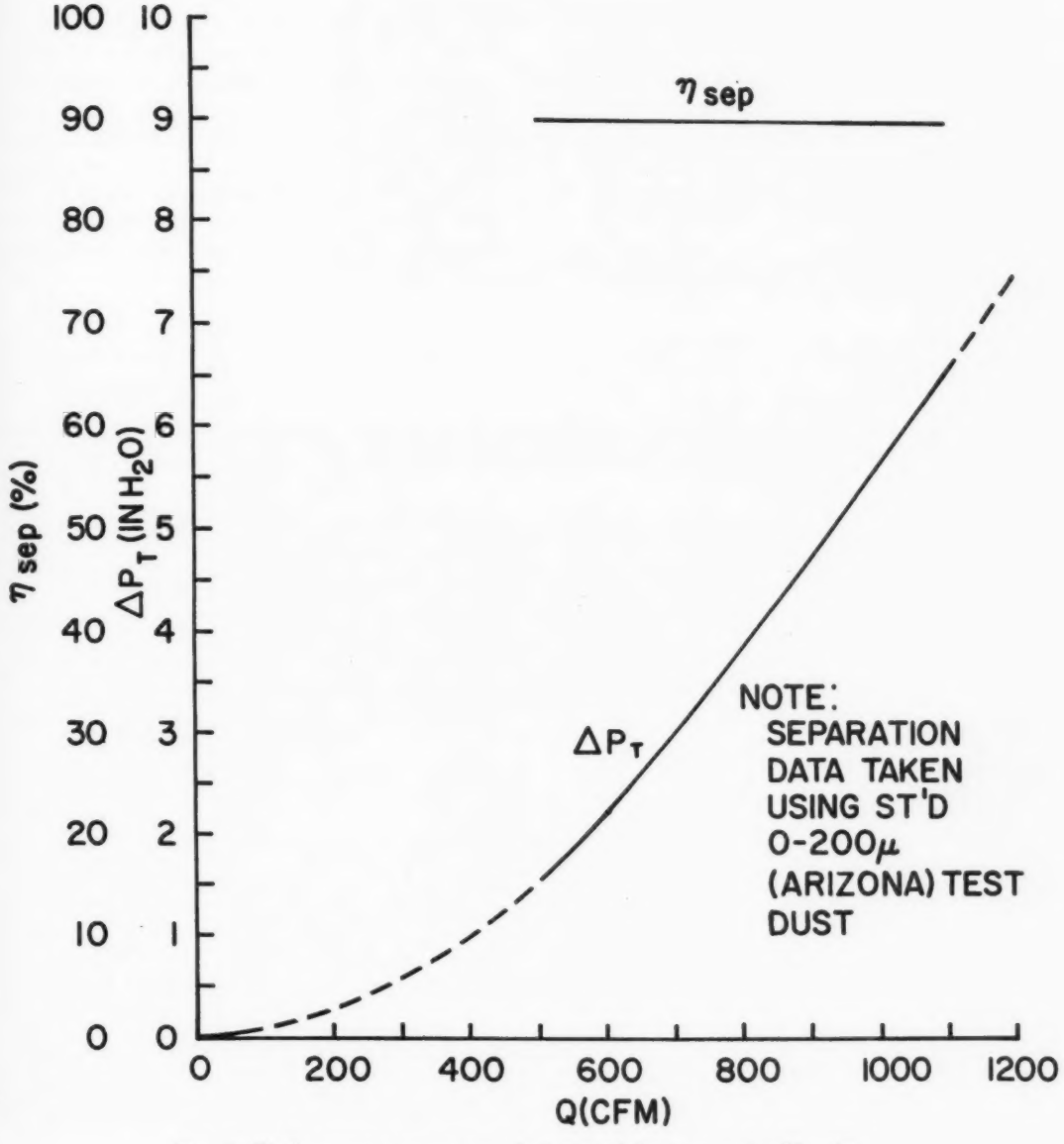

Fig. 1. Performance parameters of clustered dust separator-16 units.

The average separation efficiency obtained from the Yuma field tests was slightly greater than 93 per cent. These results were generally independent of the dust concentration in which the vehicle was operating. Figures 4 and 5 show the extremes of a light and heavy dust concentration. The last test (3a) was run completely in heavy concentrations as shown in Figure 5. The zero-zero visibility condition was so extreme that an observer riding in the passenger seat of the test vehicle could not see the test-vehicle driver sitting next to him during most of the test.

Although many vehicle mechanical problems were encountered during this series of tests, none of these failures were associated with the dust separator. There was no engine degradation from dust ingestion. The dust separator had functioned during these tests as designed, and the engine was properly protected from the dusty environment.

Although this separator functioned as designed, and the engine was properly protected, it does not satisfy as yet the optimum requirement for field units. In Jan. 1967 a second-generation prototype separator will be completed. This unit will have the same pressure-drop and flow-rate characteristics as the first; however, it will separate dust with a much greater efficiency. It will be designed to separate ~98% of standard AC Arizona road dust. Work beyond this unit will be concentrated on increasing the airflow capacity of this type separator. Preliminary testing is continuing on units with a slightly modified flow pattern which will better than double the flow capacity. These units should then have a compactness, separation efficiency, pressure drop and minimum dust-ejection energy compatible with airborne small mass flow gas-turbine engines. ★

REFERENCE

(1) Journal of the Armed Forces, 6 Aug. 1966.

Fig. 2. Turbine-powered jeep before mounting dust separator.

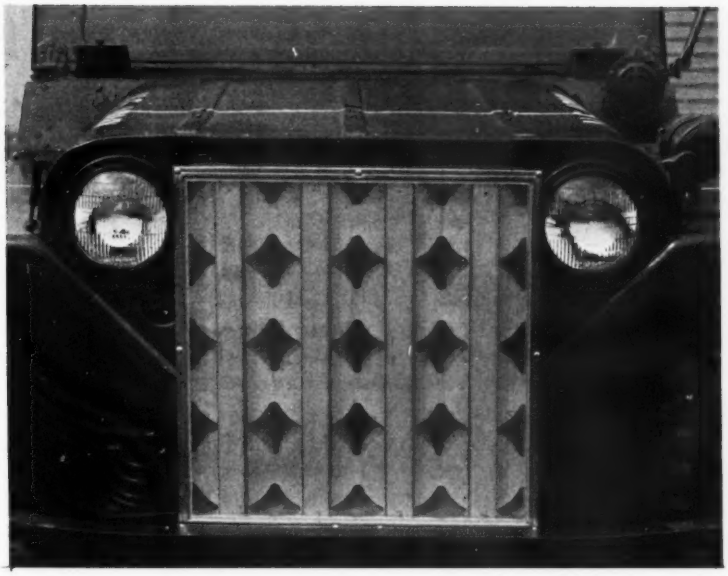

Fig. 3. Turbine-powered ieep with ARL dust separator.

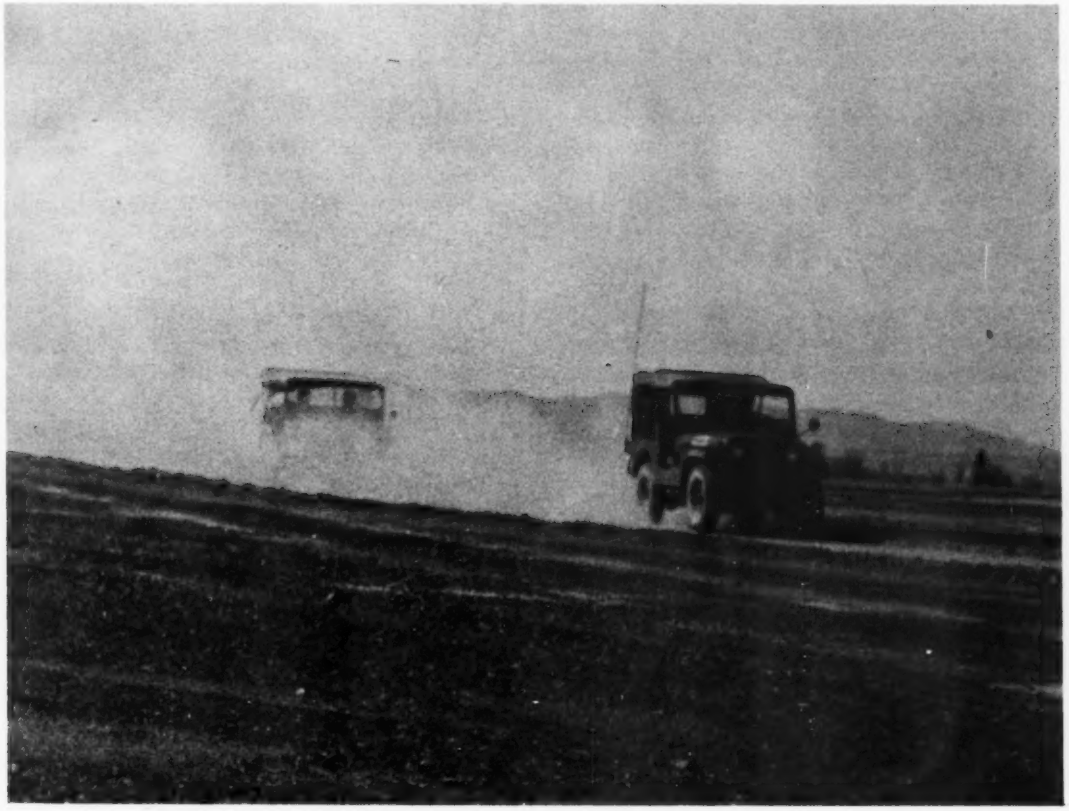

Fig. 4. Test vehicle being operated in area with light concentration of dust.

Fig. 5. Test vehicle being operated in area with heavy concentration of dust. Snorkel unit shown was added to correct vehicle oil-cooling deficiency.

THERMOLUMINESCENCE OF ICE

SPACE PHYSICS LABORATORY, AFCRL

A technique that may help scientists to interpret the geological history of ice fields has been studied by Dr. L. B. Ronca of AFCRL. This technique, which consists of glow-curve measurements, is one that crystallographers have used for some time to analyze crystals. However, it has not previously been applied to problems in geology. Glow-curve measurements involve the thermoluminescent properties of crystals that have been subjected to ultraviolet irradiation.

When ice at liquid-air temperatures is subjected to ultraviolet radiation, energy is absorbed and later released as the temperature of the ice rises once the ice is removed from the liquid-air environment. Thermoluminescence in ice is more pronounced at certain temperatures than at others--that is, peaks of maximum thermoluminescence occur in certain temperature regions. In ice, two peaks are found--a narrow one at approximately -190 degrees C, and a broader one at about -140 degrees C. The ratio of the heights of the peaks is directly related to the stress history of the ice. The ratio systematically increases from fresh snow, through compacted snow, clear unstressed ice, firm glacier ice and glacier ice with flow structure. The ratio of the heights of the peaks ranges from 0.32 to 3.12.

Dr. Ronca also conducted experiments with artificial ice and with ice that had been subjected to pressures as high as 60 Kg/cm^2. In all cases, it was shown that the higher the pressure that the ice had been subjected to, the greater the thermoluminescence.

The study of the thermoluminescence of ice, now completed, was part of a larger study of thermoluminescence as a technique for geological paleontological dating. Dr. Ronca has also studied the thermoluminescence of limestone to detect the period during which sedimentary limestone strata were formed. He reported on both his ice and limestone studies at the NATO-AFCRL Advanced Institute on the Application of Thermoluminescence to Geological Problems, September 15-25, 1966, in Spoleto, Italy. ★

DIRECT PENETRATION OF SOLAR PARTICLES INTO THE MAGNETOSPHERE

SPACE PHYSICS LABORATORY, AFCRL

Where do the charged particles in the earth's radiation belts come from? They come from the sun. But doesn't the physics of the situation dictate that these charged particles cannot penetrate the earth's magnetic field? And if this is so, how do they get through?

The most widely accepted theory is that they enter during the night, through the back door--that is, they stream past the boundary of the magnetic field (the magnetopause) on the earth's sunlit side and along the extended tail of the magnetic field on the side away from the sun. At some point where the lines of force are weak, they enter and work their way back toward the earth where they are trapped in the earth's radiation belts.

While this may, in fact, account for most of the particles, Dr. Allen G. Rubin of AFCRL has demonstrated in laboratory experiments that, under the proper conditions, it is possible that some charged particles from the sun may directly penetrate the earth's magnetic field. These experiments involve a laboratory model in which the solar wind-magnetic field interface is simulated.

A high-velocity plasma is generated that simulates the solar wind, producing a particle density of about 10^{14} per cubic cm, and particle velocity of about 5×10^6 cm per second. The plasma is directed into the dipole field of a pulsed coil that produces a maximum field strength of 5,800 gauss. The plasma pressure is balanced by the pressure exerted

by the magnetic field. The result is a shock front held off by the magnetic field.

But the resultant shock front is not a standing shock front. Electric- and magnetic-field fluctuations have been found both in the shock and in the flow region between the shock and the compressed model magnetosphere. Satellite measurements of the magnetic field beyond the earth's magnetosphere have also shown fluctuating magnetic fields. The observations of these oscillations in the laboratory encourage the AFCRL experimenters to believe that they are seeing phenomena which correctly model conditions in space.

These electric- and magnetic-field fluctuations would not in themselves create conditions for the direct penetration of solar-charged particles into the earth's magnetosphere. Another and more important phenomenon investigated was the effect on the shock front when the diameter of the plasma beam impinging on the magnetic field was varied. For these tests, apertures of varying diameters were used. As the plasma beam is narrowed, the shock becomes broadened and eventually disappears. In the absence of the shock, the narrow plasma beam can penetrate into the interior of the dipole field where the particles are trapped. The configuration assumed by the trapped particles resembles the Van Allen belt.

Of course, there is no aperture in space through which the solar plasma passes. But it is not unreasonable to speculate that there may exist the periodic emission of intense concentrations of particles reaching the earth in a narrow beam which would have an effect comparable to that seen in AFCRL'S aperture experiments. ★

Scientific Notes

"Venus Flytrap" Rocket Samples Leonids Showers: On 16 November 1966, AFCRL launched an Aerobee-150 rocket instrumented with a "Venus Flytrap" nose cone from White Sands, New Mexico, to collect micrometeorite particles during the Leonids meteor shower. The nose cone opened after 70 seconds of flight, exposing 4 arms, each with 2 modules containing collecting surfaces and altitude-discrimination instruments. After a collection period of about 5.5 minutes, the arms closed into the nose cone. The Leonids meteor showers are an annual event, with the cycle reaching a peak of activity every 100 years. That peak of activity occurred this November. Examination of the plates will be made by AFCRL scientists. In addition, AFCRL will provide scientists from 6 foreign countries--Switzerland, Germany, Israel, France, Australia and Japan--with small 1x3-inch segments of the collecting surfaces for examination. Pay-load weight for the experiment was approximately 290 pounds. The vehicle reached an altitude of about 117 miles. The project scientist is Robert Skrivanek. (Space Physics and Aerospace Instrumentation Laboratories)

Four Rocket Launches From Brazil: In conjunction with the 12 November 1966 solar eclipse in South America, AFCRL launched 4 Nike-Hydac sounding rockets from a site near Rio Grande, Brazil. A test round was fired on 5 November 1966 and 3 rockets were launched during the eclipse on 12 November. The experiments on board measured positive-ion mass composition, solar radiation, electron density and temperature, and positive-ion density. Instrumentation consisted of a quadrupole mass spectrometer, Lyman-alpha detector and Geiger counters, a retarding potential analyzer, a spherical ion trap, a standing-wave impedance probe, and a Langmuir probe. Each Nike-Hydac carried 412-pound pay loads to an altitude of about 115 kilometers. Data were obtained by telemetry and recorded at communications vans at Rio Grande. (Upper Atmosphere Physics and Aerospace Instrumentation Laboratories)

Solar UV: AFCRL launched an Aerobee-150 rocket from the White Sands Missile Range on 1 November 1966 to study UV solar radiation. The vehicle carried a 190-pound pay load to an altitude of 150 miles. Aboard the rocket was a grazing incidence photoelectric monochromator equipped with a biaxial solar pointing control to measure

solar radiation from 1,300 to 250 angstroms in the extreme-ultraviolet portion of the spectrum. A retarding potential analyzer was also used in an auxiliary experiment for determining ion and electron densities. During vehicle ascent, the nose cone was oriented to point the sensing elements at the sun. Data were telemetered to ground receiving stations. The project scientist is Hans E. Hinteregger. (Upper Atmosphere Physics and Aerospace Instrumentation Laboratories) ★

SOLAR TEMPERATURES AT 8.6 MILLIMETERS

MICROWAVE PHYSICS LAB, AFCRL

Sharp temperature rises occur in those regions of the sun where large solar flares take place. Measurements made with AFCRL's new 29-foot millimeter-wave radio telescope show that these temperatures may be more than twice as high as the normal background antenna temperature of 5,000 degrees K.

Since April of last year, AFCRL scientists have been using the new telescope, located on Prospect Hill in Waltham, Mass., to make daily maps of the temperature distributions over the solar disc. The program is under the direction of Dr. Edward Altshuler and Mr. Paul Kalaghan of AFCRL. The temperature data may help provide criteria for the prediction of solar proton showers that periodically emanate from the sun. These showers are a potential hazard to manned space flight, and to electronic equipment aboard spacecraft.

The highly precise 29-foot antenna has a 4.2-minutes-of-arc beam width, and a tape-driven, digital-pointing system; it employs an 8.2-millimeter Dicke-type superheterodyne radiometer. An automatic scanning program is used to generate, in discrete steps, a raster-type scan over the solar disc. By this means, antenna temperature-contour maps of the solar disc are produced.

The most obvious feature of these contour plots reflects the existence of warm and cool regions moving over the solar disc, corresponding to the slowly varying component of 8.6-millimeter solar radiation. The warm regions are closely associated with the plage (active-sunspot) regions seen in H_α light. Typically, the warm regions have temperatures about 200 degrees higher than the

background temperature of 5,000 degrees K; but on occasion they remain as much as 500 degrees K higher for an entire day.

Since the 29-foot telescope has been in operation, one large flare (that of April 12, 1966) has been observed. Temperatures 2,500 degrees K higher than the normal background were recorded during a 5-minute period of peak intensity. However, after the data from the 29-foot telescope were compared with data from optical and other radio telescopes, the AFCRL group determined that the temperature peak they had recorded was actually the second of two peaks, and that the first of the two had produced temperatures twice that of the basic level of the nonactive sun.

While the warm regions on the solar surface seem to be associated with flares and sunspots, the cooler regions seem to migrate without a predictable pattern. The low-temperature contours show very little similarity from one 48-hour period to another.

The temperature-enhanced regions probably occur in the chromospheric layers above the plage regions. Through these studies of solar temperatures in the millimeter-wave region, AFCRL hopes to uncover characteristic signatures which may be of value in proton-shower forecasting. ★

METHOD FOR ATTACHING GOLD BONDS TO SILICON CARBIDE AND DIAMONDS

SOLID STATE SCIENCES LABORATORY, AFCRL

Silicon carbide and diamond are semiconductor materials with superior resistance to heat and radiation. These materials are so hard, however, that bonds are difficult to attach. A standard technique for attaching bonds is to predeposit on the semiconductor a thin layer--a small dot--of chromium, over which is deposited a thin film of gold, also in the form of a small dot.

Fairly good bonds are, in fact, made with this double-layer film; but uniform quality in depositing the thin film is difficult to achieve. Furthermore, present processes are time-consuming. J.H. Bloom, C.E. Ludington and R. L. Phipps of AFCRL have developed a method which both simplifies the bonding of contacts to these hard semiconductors, and provides more consistent results.

Two methods are commonly used for depositing thin films of material: sputtering

Fig. 1. AFCRL's double-deposition system during the sputtering operation. The visible glow discharge is a plasma of argon ions.

and evaporation. The sputtering method has superior adherence because of its inherently more energetic process--however, its rate of deposition is considerably slower than that of the evaporation process. Equipment designed and fabricated by the AFCRL scientists incorporates in a single unit the best features of the two thin-film deposition techniques.

The sputtering operation is performed in an ionized gas created by a discharge between a hot filament and an anode. Both the target voltage and the ion current are independent variables. Therefore, the sputtering energy and the rate of deposition can be controlled independently. An electromagnet mounted around the outside of the vacuum chamber constricts and densifies the plasma from which the bombarding ions are drawn.

The evaporation source consists of a coiled heater made up of three strands of .015-inch tungsten wire. This heater is mounted inside a collimating glass tube which is open at both ends. A removable glass lid is used to cover the top of this tube during the evaporation. This opening facilitates the replacement of the tungsten heater and the addition of gold wire for further evaporations. The glass tube around the evaporation source restricts the deposition of the gold to the substrate area.

A movable shield, operated with the use of an external magnet, was also incorporated in the system. This shield is placed between the chromium target and the substrate during the first few minutes of sputtering to permit surface impurities to sputter harmlessly off the target without contaminating the substrate. When the target is cleaned, the shield is moved to one side, and the sputtered material is deposited onto the substrate. (Figure 1 shows the AFCRL system during the sputtering operation.) After the sputtering process is completed, the system is pumped to at least 10^{-6} torr before proceeding with the evaporation of the gold.

The shield is similarly placed between the evaporation source and the substrate during the initial degassing and melting of the gold. It is moved to one side for the evaporation process. ★

aurora and weather

METEOROLOGY LABORATORY, AFCRL

Auroral activity can affect wind circulations at the earth's surface. This is the implication of a study by Dr. Louis Berkofsky and Dr. Ralph Shapiro of AFCRL concerning the effects of upper-atmospheric heating processes on wind circulations in the lower atmosphere.

The continuously varying pattern of the earth's weather is primarily sustained by normal solar heating and internal atmospheric processes. If a precise model of atmospheric heating and the resultant pattern of atmospheric circulations is to be developed, the effects of various contributions to the dynamic processes which ultimately result in the earth's weather must be known. Contributions of heat by solar corpuscular radiation, which produces the aurora, however, are very small relative to other atmospheric heating mechanisms--absorption of visible light by the earth's surface and the lower atmosphere, absorption of ultraviolet radiation by ozone in the upper stratosphere, and absorption (also by ozone) in the lower stratosphere of infrared radiation from the earth. Nevertheless, corpuscular radiation is a significant heat contributor at the roughly 100-km altitude where auroras occur. (Figure 1 is a computer read-out showing temperatures in the upper atmosphere after heating by corpuscular radiation.)

The Berkofsky-Shapiro study is part of a larger program concerned with computer modeling of atmospheric circulations that has been under way for the past several years at AFCRL and elsewhere. Such modeling is the essential first step toward long-range weather forecasting. The computer model developed by the AFCRL scientists permits the effects of auroral heating to be studied under isolated, controlled conditions.

To show what is involved in computer modeling of the atmosphere, let us suppose that we know precisely all of the dynamic,

evolving, cause-and-effect relationships of atmospheric circulations. And let us suppose further that our computer has sufficient capacity to store all of the instructions and relevant data needed to perform all the integrations that will ultimately show the effects of any new energy source introduced into the system. In this ideal case, the computer-predicted effects and the subsequently observed effects will be the same.

We don't have this ideal situation, of course, but we can approximate it. In computer

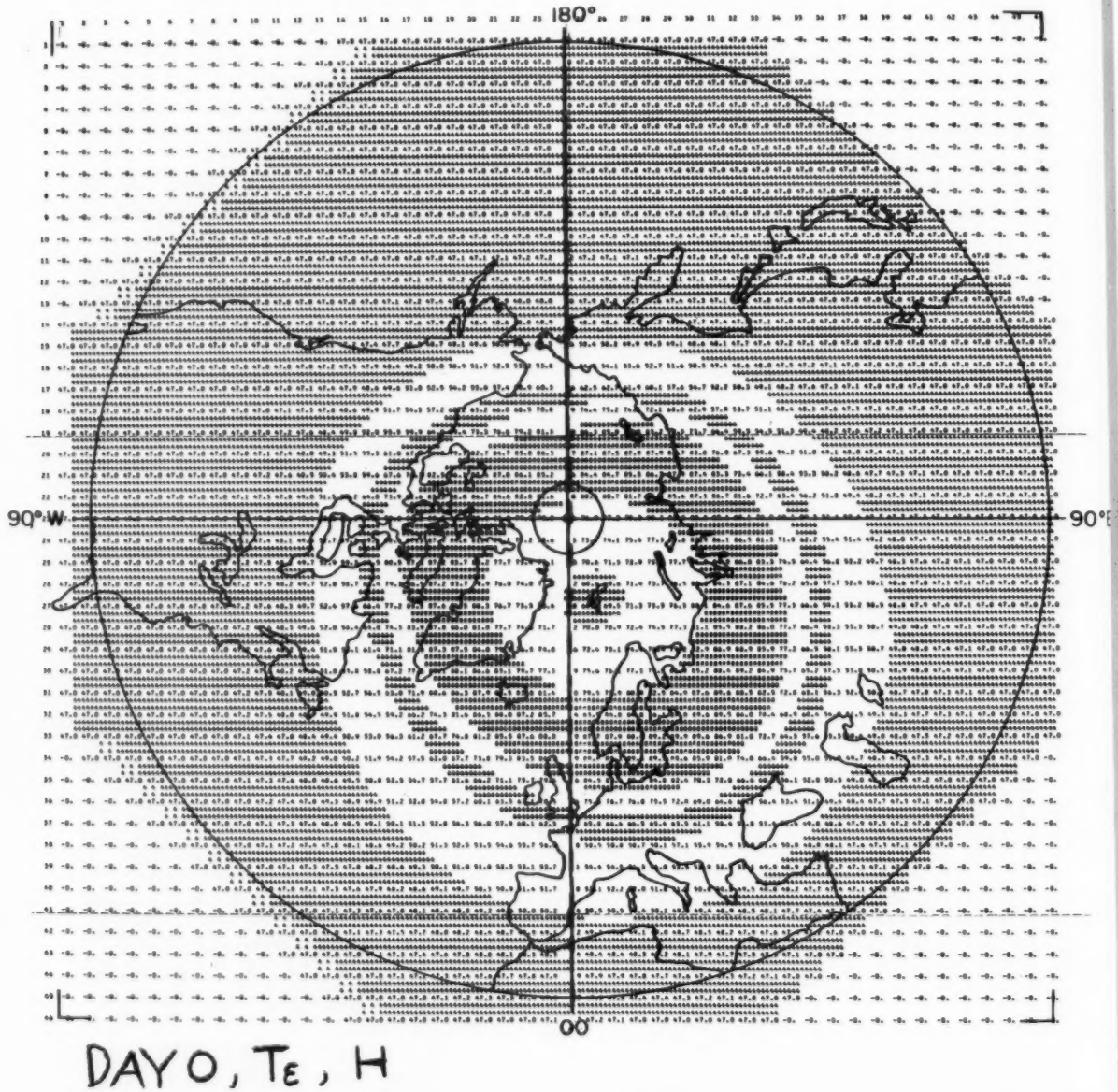

Fig. 1. This computer read-out shows temperatures in the upper atmosphere immediately following heating by corpuscular radiation resulting in the aurora. The heating in the auroral ring is clearly defined in the computer read-out.

modeling of the atmosphere, we have a simple check on the validity of our model. All we have to do is to take a real situation--the temperatures, pressures and circulations that exist at a given hour of a given day--program this into our system, and then check the resultant computer-predicted situation against the actual meteorological situation that occurred at some subsequent date.

This, essentially, is the approach of the AFCRL scientists in studying the effects of auroral heating. First, they obtained two different sets of meteorological records, one for a given date and time in January, the other for April. These records consisted of surface temperatures and the 500-mb (roughly 25,000-foot) pressure field that existed at the onset of an actual large geomagnetic disturbance. With these parameters as the starting point, Berkofsky and Shapiro introduced into each of the two separate situations an auroral storm of moderate intensity corresponding to those which actually occurred on the January and April dates.

The computer then carried out numerical integrations for each of the situations for periods of 10 days in 30-minute steps. For comparison purposes, the same initial set of conditions for the 2 days was established and integrations performed without auroral heating.

The heating and no-heating integrations developed in a similar fashion during the first two days, during which time they each resembled the real-weather development. After two days, significant differences began to develop. The greatest difference between the heating and no-heating cases showed up around the seventh and eighth days. Although neither the heating nor the no-heating forecast fields could be considered good forecasts of the actual temperature and pressure fields, the auroral-heating cases more closely resembled the observed fields both in January and April.

In summary, the modeling experiments uncovered evidence of a small but noticeable difference in the average circulation that develops between cases in which a small amount of heat is added in an auroral ring and cases in which no heat is added. The AFCRL scientists, however, point out certain deficiencies in their model which limit its usefulness in making predictions. In its present form, it is far too simplified for any purpose other than to show the possible effects of small heating perturbations at high atmospheric levels on low-level circulation.

The study of gross atmospheric circulations is a prime example of the growing use of computers in modeling dynamic physical processes, processes which are often too complex to be investigated by other means. Phenomena of great complexity can be replicated numerically and investigated under precisely controlled conditions by this technique, which promises to have a profound impact on the nature of scientific investigation. ★

Luxembourg effect in microscale

DR. K. V. N. RAO, Microwave Physics Laboratory, AFCRL

If you had happened to be in Eindhoven, Netherlands, about 34 years ago, and had just happened to be listening on 653 kc to the radio station in Bern, Switzerland, you may have heard, faintly in the background, the program of Radio Luxembourg, transmitted at 252 kc.

A quite acceptable explanation for this phenomenon, the well-known "Luxembourg Effect," soon emerged. The explanation was that the ionosphere absorbed the electromagnetic radiation from the powerful Luxembourg station. This absorption was "seen" as amplitude modulation on the radio waves from the Bern station.

This explanation is all right in a gross sort of way. Subsequently, experiments were conducted using megawatt transmitters to irradiate the D-layer, and more refined theories were developed involving alterations

of the electron density of the D-layer. Here again the theories were quite acceptable, but many of the experimental results did not conform neatly to theory, indicating that the phenomenon had unsuspected complexities. These complexities could not be unraveled in simple experiments using high-power transmitters to irradiate the actual ionosphere.

AFCRL scientists have brought the experiments into the laboratory where plasmas simulating the ionosphere could be created and experiments controlled. The object of the experiments at AFCRL is to determine: (a) the rate at which electromagnetic energy is transferred to the electron gas in atmospheric plasmas at low pressures; (b) the effect of this energy transfer on electron-loss processes such as diffusion, and attachment and recombination; and (c) the rate at which electrons lose energy to neutral particles.

In these experiments, magnetoplasmas in atmospheric gases such as O_2, N_2 or NO are created and subjected to microwave energy. A range of variables can be controlled--atmospheric gas, its purity, degree of ionization, and the appropriate frequency, duration and amplitude of the electromagnetic (EM) wave.

Results show that under cyclotron resonance absorption conditions--that is, when the frequency of microwave energy is equal to the frequency of the gyrating electrons--rapid transfer of EM energy occurs. For example, in oxygen at low pressures (less than 0.2 torr), electron energy is elevated from 0.04 electron volts to a few electron volts in less than a microsecond. With longer pulses of microwave energy, the increased electron energy causes rapid attachment to the neutral particles and thereby reduces the prevailing electron density. For medium microwave-energy levels, the electron density reaches a quasisteady plateau, indicating that a new electron-production mechanism occurs. This is caused, it is believed, by the detachment of electrons from negative ions colliding with inelastically excited neutral particles.

The AFCRL laboratory studies also illustrate the processes of electron-energy relaxation. These experiments indicate that the fraction of energy lost by an electron in colliding with a neutral oxygen molecule is about 10 times larger than that with nitrogen molecules, whereas the fraction of energy lost in NO is 10 times larger than that in oxygen. ★

a very small and very heavy satellite

UPPER ATMOSPHERE PHYSICS LABORATORY, AFCRL

A very small but very heavy satellite is being designed by AFCRL scientists. When built and launched, possibly in late 1967, the satellite will provide the most precise and detailed information to date on atmospheric densities in the region between 80 and 240 miles altitude. Atmospheric pressures and temperatures can also be derived from the data.

Knowledge of atmospheric densities in this region will permit greater accuracy in predicting ballistic-missile trajectories, satellite orbits, and splash-down points of reentering space vehicles.

The small spherical satellite will have a diameter of only 20 inches, and will weigh 1,000 pounds. To increase mass, lead filler will be added to the structural shell. The satellite will have a mass as high as 10 grams per cubic centimeter, 10 times that of the average satellite.

The high weight-to-size ratio is dictated by the function of the satellite. The perigee will be the lowest of any satellite launched to date--about 80 miles--which will take it relatively deep into the earth's atmosphere. The mass of the satellite (and its smooth spherical exterior) will reduce the effects of atmospheric drag, permitting it to remain in orbit for an extended period in spite of its low perigee.

One source of atmospheric-density data will be observations of satellite orbit perturbations. These data can be derived from a knowledge of the satellite's area-to-mass ratio, drag coefficient and velocity. A unique

feature of the satellite will be a specially developed triaxial acceleration-sensing system which will largely fill its interior.

Of particular interest to upper-atmosphere scientists are short-term fluctuations in atmospheric density. Weather patterns, analogous to those experienced at ground level, exist at satellite altitudes. In these patterns, pressure, density and temperature vary with altitude, longitude and time. The continuous short-time resolution measurements made by the satellite will provide data for weather charts of the atmosphere above 80 miles.

Dr. Kenneth S. W. Champion of AFCRL, who is responsible for the over-all atmospheric-density-measurements program, is in charge of designing the satellite. ★

FILAMENTS IN ELECTRICAL-CURRENT FIELDS

KENNETH R. CRAMER, Thermomechanics Research Laboratory, ARL

Magnetofluid dynamic and electrical devices that utilize high-temperature gases to conduct the current are usually designed on the assumption that their current fields are uniformly distributed over the electrodes. However, the electrical conductivity of a gas increases with temperature, with the result that a local increase in temperature produces increased ohmic heating, which again increases the gas temperature. Current fields in high-temperature gases may consequently be unstable, and could perpetrate damage or bring about reduced performance.

In a recent ARL report (1), the stability of a uniform current field in a nonflowing radiating gas between parallel plate electrodes was examined for a temperature disturbance along a plane perpendicular to the electrodes. The thermal conductivity and power radiated were represented as functions of temperature from experimental data, and the temperature disturbance was characterized by an arbitrary-strength Dirac delta function along the plane of the transverse center line. An appropriate energy equation was solved to determine the subsequent growth or decay of the disturbance θ, with the result that

$$\theta = \frac{\phi\, |x|\, e^{(\alpha c_3 t - x^2/4\alpha t)}}{2\sqrt{\pi \alpha\, t^3}},$$

where x is the dimension parallel to the electrodes, α the thermal diffusivity, t the time, and ϕ an arbitrary disturbance strength. The coefficient c_3 is: $c_3 = c_1E^2 - c_2$, where E is the constant voltage gradient applied across the electrodes, and c_1 and c_2 are the rates of increase of the electrical conductivity and radiated power with temperature. These results demonstrate that uniform current fields in continuum gases are unstable for arbitrarily small temperature disturbances since generally $c_1E^2 > c_2$ and as $t \longrightarrow \infty$ then $\theta \longrightarrow \infty$ when $c_3 > 0$ for any non-zero ϕ, no matter how small. However, if the electrical-conductivity function should have a knee, i.e., $c_1 = 0$, or the gas contains a seed that can dissipate or absorb the disturbance, then stability can be achieved. Also, it could exist when $c_1E^2 \leqq c_2$.

Since most high-temperature gases were predicted to be unstable for a local increase in the temperature, then small high-temperature filaments or arcs would be produced in the gas between the electrodes. Such filaments have been reported in flowing gases and with magnetic fields. These filaments produce electrode spot burning and may be responsible for the failure of Hall devices to produce their expected Hall potentials.

Since filaments, or current sheets in the two-dimensional case, were predicted, half-widths were calculated, assuming various steady filament-center-line temperatures for argon and nitrogen and two applied voltage gradients. Representative heat-flux potential and current distributions were also calculated. Filaments were found to be very thin and their size not strongly dependent on

the peak heat-flux potential.

Concurrent with the formation of the filaments, the electrical circuit may respond, depending on its specific design. A characteristic response time of the gas was considered to be useful for estimating the nonstationary behavior of the complete circuit. The time for the filament-center-line heat-flux potential to drop to half its value was estimated to be one tenth of a microsecond for argon, and one microsecond for nitrogen.

The formation of numerous shorting filaments between adjacent electrodes in magnetohydrodynamic Hall and segmented electrode devices was suggested as the cause of Hall potential losses. ★

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a method of decoding speech

ROWENA W. SWANSON
Directorate of Information Sciences, AFOSR

Speech is an almost universal tool for human communication. Artificial-speech production has long been a goal of inventors and scientists. A delightful and beautifully illustrated book, Automata, describes several talking heads and talking machines conceived in the 18th and 19th centuries. (1) Faintly reminiscent of modern times is the following excerpt about the work of one inventor that appeared in a Paris journal in 1778:

> "Monsieur L'Abbé Mical continues to exhibit his two talking heads to the public, but since he is not a schemer, since he is working on his own without organized support or without accomplices, since he has not bribed anyone to puff him and has not secured the goodwill of the newspaper writers, little has been heard of his machines, which have secured the widespread admiration of natural philosophers. Indeed, however imperfect his machine may be, it has solved the problem which had been believed insoluble from Archimedes to Vaucanson." (2)

The Abbé, however, is said to have considered his work unworthy of this praise, and destroyed the heads.

Hermann von Helmholtz and others have scientifically investigated speech synthesis. Modern machine-oriented speech research, however, can be dated from H. Dudley's work (1939) on the vocoder. (The vocoder is a band-width compression system that analyzes and subsequently resynthesizes speech from transmitted control signals.) Air Force interest in efficient methods of analyzing and synthesizing speech is associated with their applications in communication systems. Additionally, by-products of speech research could include, from a behavioral-science viewpoint, a better understanding of principles of human communication--and, from a machine-intelligence viewpoint, the realization of complex decision-making tasks.

The 18th and 19th century efforts were concerned with speech synthesis, that is, the production of sounds that human listeners could understand. Alexander Graham Bell, Dudley, and others attacked the problem of automatic speech recognition, that is, machine decoding and translation of the speech signal to an equivalent that could be expressed by a sequence of symbols, including printed words. Automatic recognition has been less tractable than synthesis because of ambiguities and irregularities in the speech signal. Even the speech of a single individual can yield a variety of patterns of shifting resonances produced by his articulatory system as the result of modifications of the shape and size of his vocal cavity. Additionally, the articulatory system varies from individual to individual. Basic research is still needed to answer such fundamental questions as: (a) how to select an adequate set of measurements; (b) how to define linguistic units that will be basic to a machine; (c) determining the best method of representing utterances and words so that a machine can recognize and process them; and (d) how to segment the duration (length of time) of the speech signal.

Under grant AF-AFOSR-7-66, the Biologi-

cal Computer Laboratory at the University of Illinois has been concerned with discovering principles of biological computation and applying them in the design of electronic systems. To emulate the human recognition of speech, it is hypothesized that a machine must be able to determine the invariants in the speech signal. In a recent report, under grant sponsorship, Jenö Gazdag summarizes his theoretical and empirical research which has resulted in a simplified method for automatically decoding the speech signal. (3) Gazdag's method uses "machine events" as the basic linguistic units, in contrast with phonemes and other units that have been employed by others. The machine events are represented as multidimensional binary vectors. Utterances of words are expressed as sequences of binary vectors. Spoken words are decoded as subsequences of machine events. Decoding is independent of time, i.e., it does not depend on the duration of the speech signal. In the schematic of Gazdag's decoder (Figure 1), the Processor has the task of transforming the speech signal to machine events. The Translator converts the sequences of events to output messages.

The Processor is composed of a short-time spectrum generator (STSG) that receives the speech signal, and a machine-event generator (MEG). The STSG is a set of k contiguous band-pass filters followed by rectifiers and smoothing (low-pass) filters. Gazdag's principal contribution is the development of a theoretical method of determining the optimum band width of the filters in terms of their frequency response and distribution. He develops the method in the report for a pair of neighboring band-pass filters that can be extended to k filters. The distribution he suggests is aimed at obtaining a short-time spectrum that can maximally reduce the average uncertainty about spoken words. The fundamental idea is expressed in the following axiom: given k band-pass filters with center design frequencies ω_i (i = 1, . . . , k), the filters are optimally distributed over a given frequency range $\omega_1 \leq \omega \leq \omega_k$ if each frequency band $\omega_i \leq \omega \leq \omega_{i+1}$ (i = 1, ..., k-1) contributes an equal amount to the intelligibility (articulation index) of speech.

Gazdag suggests that a machine event can be viewed as the machine representation of a set of articulatory positions of the speaker's vocal tract. He postulates that, when a speaker generates a word, his articulators move simultaneously and continuously to produce a sequence of articulatory positions. When the speaker utters a word or part of a word, he executes approximately the same sequence of articulatory gestures whether he speaks slowly or rapidly. This suggests that information about the identity of the spoken word is represented by the order of occurrence of machine events, but not by their duration; the duration provides an indication only of the rate of utterance. Subsequent machine events can thus be specified as precisely one Hamming distance apart. This Hamming-distance restriction drastically reduces the number of "next" machine events that are

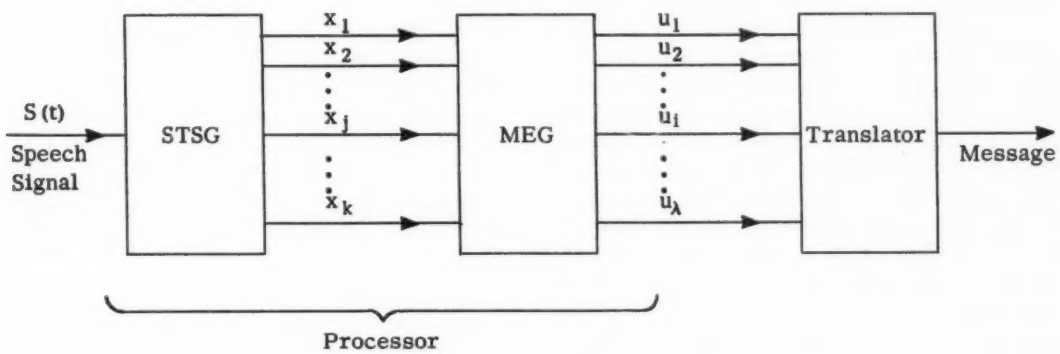

Fig. 1. Schematic of the Decoder

available for selection in a sequence, and facilitates the rapid identification of a spoken word.

Experiments were conducted with a 12-channel STSG and an MEG that implemented 6 hyperplanes. Five hyperplanes were found sufficient to categorize the vowels based on data from the recordings of STSG outputs for 5 speakers (2 females, 3 males) for 9 English vowels spoken in context. (4) The 6th hyperplane was set to obtain discrimination between fricative sounds characterized by dominant frequencies over 3,000 cycles/sec., (e.g., "s" in six), and vowel sounds whose dominant frequency ranges are below 3,000 cycles/sec. (The 200 to 3,000-cps range, in which about 70% of speech information in the English language is transmitted, was considered in this study). In the experiments, the role of the Translator was assumed by a human who transcribed the 6 recorded outputs of the MEG into sequences of 6-digit binary-number representations. Translation by a machine, however, is envisioned as a process of generalization over utterances, that is, the detection (in Gazdag's terms) of "significant subsequences of machine events." These significant subsequences are the common subsequences of machine events in k number of transitions that correspond to k number of separate utterances of a word.

Gazdag's use of short-time spectra is based on findings, from vocoder and other research, that the spectra contain sufficient information for speech recognition and resynthesis. His method of hyperplane partitioning seeks to be most efficient from an information-processing viewpoint. Thus, it is desirable that each partition bisect the measurement space to give the greatest reduction of uncertainty about the reference vectors. A principal source of difficulty, however, is that, even during the utterance of a single vowel sound, the vocal tracts and the short-time spectrum change. More hyperplanes give better classification of the speech sound, but also increase the complexity of the decoder and the processing of the transitions of machine events. A trade-off exists, therefore, between the degree of accuracy of decoding and cost, complexity, etc.

Gazdag tested his method against the recordings of 5 utterances for each of 10 words (the 10 digits, 0 to 9) by each of 4 speakers. He thus compared significant subsequences of machine events from a total of 20 transitions for each word. The best results (i.e., smallest probabilities of decoder confusion) were obtained for the words, "one" and "nine"; the poorest results were obtained for "eight." He found that significant subsequences for some words are included in the transitions of machine events of other words. However, he believes that, though this phenomenon is likely to occur for short subsequences of machine events, it is unlikely to occur for relatively long significant subsequences. For example, though the significant subsequence for the word, "eight," occurred in the transitions of several words, no significant subsequence of the other words occurred in the transitions of the word, "eight." Moreover, the test words were decoded unambiguously.

Gazdag notes that, to achieve accurate decoding of a large number of words (for example, about 1,000) for a large number of speakers, a more complex device than his experimental apparatus would be needed. The number of channels of the STSG and the number of partitioning hyperplanes would have to be increased. However, since the number of distinguishable output states of the Processor increases exponentially with the number of partitioning hyperplanes, he anticipates that complexity will converge to a practical limit with an increasing number of words. Gazdag's method is thus one feasible approach to a speech-recognition device that can provide rapid convergence to a unique representation of text spoken by various individuals under various conditions.

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sign principles for the Processor, and computation of the significant subsequences from transitions of the machine events. Appendices include tables of transitions and significant subsequences, and a description of the method for computing filter band widths.)

(4) The vowel sounds are those in the words eat, it, bet, sat, but, father, lost, put, and cool.

the synthesis of gallium hydride

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There has been considerable interest recently in the semiconductor properties of Groups III and IV compounds of the periodic table of elements, such as indium antimonide and gallium arsenide. The latter compound is of especial interest since the solid was shown to emit coherent or laser light when a current of electricity was passed through a properly mounted crystal of this material. Thus, the chemistry of gallium and its compounds is of interest to the Air Force.

Prof. N. N. Greenwood of the University of Newcastle, Newcastle upon Tyne, has been partially supported by an AFOSR grant for several years. He has worked on Group-III-elements chemistry, particularly that of boron and gallium. In the literature it has been shown for some time that experiments designed to liberate gallium hydride from its adducts have resulted in its immediate decomposition into its elements, i.e., hydrogen and gallium. It was therefore quite an achievement when unco-ordinated gallium hydride was synthesized for the first time. The reaction used by Prof. Greenwood in preparing unco-ordinated gallium hydride involved the action of boron trifluoride on the trimethylamine adduct of gallium hydride.

$$Me_3NGaH_3 + BF_3 \xrightarrow{-15^{o}} GaH_3 + Me_3NBF_3$$

The products of this reaction were a liquid, GaH_3, and a white solid, Me_3NBF_3. The liquid was stable at -15^{o} centigrade, but decomposed quantitatively at room temperature into metallic gallium and the expected amount of hydrogen. The new material, gallium hydride, was a viscous oil which was insoluble in most nonco-ordinating or nonadduct-forming solvents. It was quite soluble in dimethyl sulfide, and is known to form an adduct with this compound. The infrared spectrum of the oil was found to be compatible with that expected for gallium hydride.

Thus, for the first time, free or unco-ordinated gallium hydride has been prepared. This new knowledge regarding gallium and its compounds has not yet been put to practical use. However, its application will undoubtedly be effected some time in the future, now that this new compound has been isolated and characterized. ★

pressure shift of the ruby spectrum

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Because ruby is such an important lasing material, it is of considerable interest to be able to predict theoretically the pressure dependence of its spectra. This can be done using classical crystal-field theory if the pressure dependence of the crystalline-field parameter Dq, and of the Racah coefficients B and C, are known. These three parameters, when substituted into the matrices first determined by Tanabe and Sugano (1), determine the pressure dependence of all 3d Cr^{3+} energy levels in Al_2O_3.

Let us first briefly review crystal-field theory. In an isolated Cr^{3+} ion, the outer three 3d electrons couple to form energy levels of definite orbital momentum. (We ignore the small spin-orbit splitting.) The ground state is a ^4F state, while excited states start with ^4P, ^2P, ^2G, etc. These states are separated in energy because the mutual electrostatic repulsion energy of the three electrons depends upon the way they are coupled. For the d electrons, the energy separation of the atomic levels can be characterized completely by the two Racah parameters, B and C.

When the Cr^{3+} ion replaces an Al ion in Al_2O_3, two things happen. The Cr^{3+} electrons see an additional electrostatic potential due to the other ions in the crystal. This potential has the same symmetry as that of the ions giving use to it. In ruby, it is a good approximation to assume that the potential has cubic symmetry. (The trigonal potential is relatively small, and is responsible for the small splitting of the ruby R lines, for example.) The cubic potential, whose strength is measured by the parameter Dq, splits the

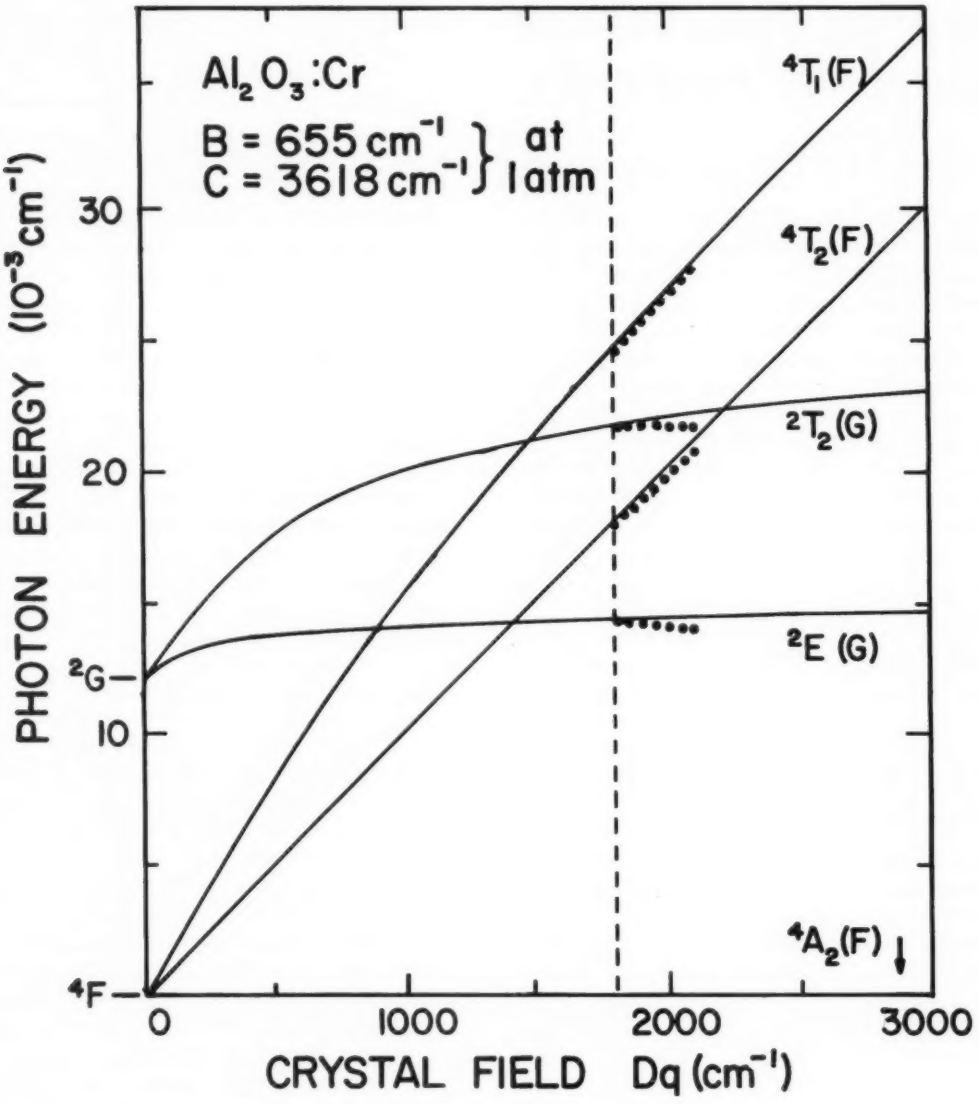

Fig. 1.
The energy levels of Cr^{3+} as a function of the crystal field of octahedral symmetry. The dashed vertical line indicates the crystal-field value for Al_2O_3 at atmospheric pressure. Dotted lines show linear extrapolation of pressure derivatives.

atomic energy levels into levels whose wave functions reflect the cubic symmetry of the potential. Figure 1 shows the splitting of the atomic ^4F and ^2G levels in the cubic crystalline field as the strength of the field is increased. (The ^2G state actually splits into four states, of which only two are relevant here.)

The second effect when a Cr^{3+} ion substitutes for an Al ion is that the Cr 3d electron-wave functions overlap neighboring ions. The outer part of the wave function has thus lost its atomic character, and the parameters B, C, and Dq, which are all determined by averages over the atomic-like part of the wave functions, are likewise diminished in value. Covalency, therefore, lowers all energies relative to those of the free ion.

Thus, the broad outline of the ruby spectrum can be described quantitatively by the three parameters B, C, and Dq. If the pressure-dependence of these parameters is known, the pressure shift of any ruby level is in principle known, neglecting the pressure-dependence of the spin-orbit, trigonal, and spin-spin exchange effects, which are relatively small.

Stephens and Drickamer (2) measured the pressure coefficients of the two Ruby bands at 18,000 and 24,700 cm^{-1}. According to classical crystal-field theory, the band at 18,000 cm^{-1}, identified with the transition $^4A_2 \longrightarrow {}^4T_2$ (trigonal and spin-orbit splittings are ignored), depends only upon Dq, while the band at 24,700 cm^{-1}, identified with the transition $^4A_2 \longrightarrow {}^4T_1$, depends upon Dq and B.

The pressure shift of the ruby R lines have now been measured up to 10 kilobars. The lines are identified with the electronic transition $^4A_2 \longrightarrow {}^2E$, where the cubic ^2E level is split by the trigonal crystal field. This transition is nearly, but not completely, independent of Dq, and it also depends upon the Racah B and C parameters. Our results thus enable us to determine the pressure shift of C.

Some time ago we built in this Laboratory an apparatus capable of generating truly hydrostatic pressures up to 18 kbars (260,000 PSI) at room temperature, and up to 14.14 kbars at 77.3°K (205,000 PSI at minus 320°F, the boiling temperature of liquid nitrogen). (3) We established that the latter value is the limit for any hydrostatic application of pressure at this temperature because the pressure-transmitting medium, gaseous helium, solidifies at this point. (4) This apparatus, the first one built anywhere to reach these extreme pressures at such low temperature, was used previously by us for numerous investigations of the band-structure parameters and optical properties of II-VI compounds. It was easily adapted for the present task where we required pressures up to 10 kbars and optical windows (1/2" dia by 1/2"-long sapphire) for transmission measurements.

The Al_2O_3 crystals used were obtained from the Linde Company. The R lines were measured spectrographically in absorption on 5-mm-thick samples with concentrations of 0.005 to 0.05 per cent Cr. Samples with higher Cr concentration showed excessive line broadening which made the determination of the line shift more difficult. The R lines shifted toward lower energy with pressure. The shift was linear in the investigated range, and had the value -0.9 ± 0.05 cm^{-1}/kbar.

Figure 1 shows the lower energy levels of the Cr^{3+} ion in their dependence on the crystal-field parameter Dq. The parameters chosen for Al_2O_3 were B = 655, C = 3,168, and Dq = 1,800 cm^{-1}. The experimentally determined pressure dependence is indicated by the dotted lines. They indicate the location of energy levels and Dq values with increasing pressure derived from the linear pressure coefficients. Their right ends correspond to a pressure of 300 kilobars, and are the result of a linear extrapolation of the pressure dependence at atmospheric pressure. Departures from this linearity will probably occur at about 80 kilobars.

The pressure shifts of the four Cr levels which have been measured are given in Table I, together with the corresponding cubic crystal-field identification. The values of the classical crystal-field parameters Dq, B, and C were fit to these lines. Each param-

eter was then varied individually to determine theoretical values of

$$\frac{\partial E_i}{\partial Dq}, \quad \frac{\partial E_i}{\partial B} \text{ and } \frac{\partial E_i}{\partial C}$$

where i indicates a particular transition. The four measured pressure shifts thus give four equations in three unknowns.

$$\frac{\Delta E_i}{\Delta P} = \left(\frac{\partial E_i}{\partial Dq}\right)_{theor}\left(\frac{\Delta Dq}{\Delta P}\right) + \left(\frac{\partial E_i}{\partial B}\right)_{theor}\left(\frac{\Delta B}{\Delta P}\right) + \left(\frac{\partial E_i}{\partial C}\right)_{theor}\left(\frac{\Delta C}{\Delta P}\right) \quad (1)$$

$$i = 1, 2, 3, 4$$

The least-squares values for the linear pressure dependence of Dq, B, and C are given in Table II. The values for Dq and B agree with the graphs of Stephens and Drickamer. The least-squares values were then substituted back into equations (1) to obtain an estimate of the goodness of fit. (Table I). These values, when used in conjunction with the matrices of Tanabe and Sugano, will thus determine the linear pressure shift of all of the ruby lines identified with 3d-electron transitions in the cubic crystalline-field approximation.

Using the compressibility data of Bridgman, (6) Stephens and Drickamer estimated the theoretical pressure dependence of Dq, assuming the classical crystal-field-theory result that Dq is inversely proportional to the interatomic spacing raised to the fifth power. This result is in close agreement with the experimental determination of $\Delta Dq/\Delta P$. However, the later compressibility results of Hart and Drickamer (7) yield a theoretical shift which is smaller than the experimentally observed one. Both of these results, listed in Table III, are too small if one thinks in terms of covalency because, upon compression, the $1/r^5$ effect will enhance Dq, while the increased covalency should diminish Dq as it diminishes B and C. If one assumes a constant covalency factor equal roughly to $\Delta B/B$ or $\Delta C/C$, Dq should be lessened due to covalency by about 0.1 cm^{-1}/kbar. The experimental pressure

Table I
Ruby Lines and their Experimental and Computed Pressure Shifts.

Energy (cm^{-1})	(Cubic) Transition	Experimental Pressure Coeff. (cm^{-1}/kbar)	Computed Pressure Coeff. (cm^{-1}/kbar)	Source
14,400	$^4A_2 \longrightarrow {}^2E$	-0.9 ± 0.05	-0.98	Langer and Euwema
		-0.95 and -0.84*		Paetzold (5)
18,000	$^4A_2 \longrightarrow {}^4T_2$	10.5	10.5	Stephens and Drickamer (2)
24,700	$^4A_2 \longrightarrow {}^4T_1$	11.1	11.1	Stephens and Drickamer (2)
21,800	$^4A_2 \longrightarrow {}^2T_2$	-0.12	-0.06	Paetzold (5)

* Paetzold gives two values corresponding to the R lines.

shift of Dq should consequently be about 0.1 cm^{-1}/kbar below the one derived from compressibility data. This is evidently not the case, perhaps because of increased local compressibility in the neighborhood of the Cr impurity ion. ★

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Table II
Pressure Shifts of Dq, B, and C, Derived from Experimental Values of Table I.

Parameter	Value (cm^{-1})	Pressure Coeff. (cm^{-1}/kbar)	Pressure Coeff. of Stephens & Drickamer (cm^{-1}/kbar)
Dq	1,800	1.05	1.05
B	655	-0.03	-0.2
C	3,168	-0.35	

Table III

$\frac{\Delta V/V}{\Delta P}$ (1/kbar)	$\frac{\Delta Dq}{\Delta P}$ (cm^{-1}/kbar)	Source
$3.55 \cdot 10^{-4}$	1.07	Bridgman (6)
$3.13 \cdot 10^{-4}$	0.94	Hart & Drickamer (7)

PROFILES

Mr. Paul M. Kalaghan is a research physicist with the Transmission Branch, Microwave Physics Laboratory, AFCRL. He is presently conducting solar observations at millimeter wave lengths to gain information on millimeter-wave disturbances on the sun and their association with optical solar flares and solar proton showers. Together with Dr. Edward Altshuler, also of AFCRL, he is directing a program, through the use of a new telescope, to make daily maps of the temperature distributions over the solar disc. An article on this work, "Solar Temperatures at 8.6 Millimeters," appears in this issue of the Review. Mr. Kalaghan received his B.A. in Physics in 1956, and his M.S. in Applied Physics in 1957, both from Harvard. He is a member of the American Association for the Advancement of Science.

Dr. K. V. Narasinga Rao, author of "Luxembourg Effect in Microscale" which appears in this issue of the Review, is a research physicist in the Microwave Physics Laboratory, AFCRL. He received his B.Sc. (Hons) in Physics from Andhra University, Waltair, India, in 1952, his Diploma of the Indian Institute of Science in Electrical Technology (D.I.I.Sc., E.T.) in 1955, and his M.S. and Ph.D. degrees in Electrical Engineering from the University of Illinois, Urbana, Illinois, in 1957 and 1962, respectively. Dr. Rao is a member of the American Physical Society, the American Geophysical Union, Sigma Xi, and the Institute of Electrical and Electronics Engineers.

Dr. Allen G. Rubin, a physicist with the Space Physics Laboratory, AFCRL, received his Ph.D. from Boston University in 1957. From 1957-1958, he studied nuclear reactions at the Electronuclear Division, Oak Ridge National Laboratory. Later, from 1959 to 1963, while employed by the Williamson Development Company of West Concord, Massachusetts, he did research on the acceleration of electrons in plasmas. Since coming to AFCRL in 1963, he has been engaged in laboratory experiments on plasma interaction with magnetic fields. His work is discussed in the article, "Direct Penetration of Solar Particles into the Magnetosphere," which appears in this issue of the Review.

Dr. Ralph Shapiro, Chief of the Dynamics Branch, Meteorology Laboratory, AFCRL, has been working since 1952 on problems concerned with the general circulation of the earth's atmosphere and the associated problem of solar-terrestrial relationships. Using a fundamentally new approach, he has presented the first substantial evidence of a real response of the tropospheric circulation to variable solar-energy emission. Currently, he is attempting to study such atmospheric responses theoretically, by the numerical integration of mathematical models of the atmosphere that incorporate solar variability as an external energy source. Dr. Shapiro has a B.S. in Education from Bridgewater Teachers College (1943), and an S.M. and Sc.D. in Meteorology from M.I.T. (1948 and 1950, respectively). He is a member of the American Meteorological Society, the Royal Meteorological Society, the American Geophysical Union, and RESA. The article, "Aurora and Weather," in this issue of the Review, describes the recent work of Dr. Shapiro and Dr. Louis Berkofsky, also of AFCRL.

Dr. Luciano B. Ronca, a physical scientist at the Space Physics Laboratory, AFCRL, has an M.S. in Geology (1959) and a Ph.D. in Geology (1963), both from the University of Kansas. He was for awhile Acting Director of the Division of Geochemistry and Nuclear Geology of the Department of Geology, University of Kansas. Presently, he is conducting a systematic research program on the specific problem of the origins and subsequent developments of lunar and planetary features, and their significance to present environments. He is using all available means of gathering information -- from physicochemical studies of terrestrial rocks and minerals to direct observations of the moon and planets. The article, "Thermoluminescence of Ice," describes some of his current work.

Dr. Kenneth S. W. Champion has been Chief of the Atmospheric Structure Branch, Upper Atmosphere Physics Laboratory, AFCRL, since 1963, and a full-time AFCRL staff member since 1959. He became an assistant professor of physics at Tufts University in 1954 and, during part of 1964, was visiting professor of physics at the University of Adelaide, Australia. Dr. Champion received his B.S. with Honors in Physics and Mathematics from the University of Sydney, Australia, in 1944, and his Ph.D. in Electron Physics from the University of Birmingham, England, in 1951. He was previously awarded a British Council Travelling Scholarship (1947), and has held a research fellowship from the Australian National University (1949-1952). He is a member of the American Physical Society, the Physical Society of London, RESA, and the American Geophysical Union. Dr. Champion is in charge of designing "A Very Small and Very Heavy Satellite," described in this issue of the Review, to provide precise information on atmospheric densities.

Miss Charlotte E. Ludington (left), Mr. Robert L. Phipps (center), and Mr. Jerome H. Bloom (right), all of the Device Physics Branch, Solid State Sciences Laboratory, AFCRL, have developed a method for bonding contacts to hard semiconductors which is simpler and more consistent in its results than previous methods. It is described in this issue of the Review in "Method for Attaching Gold Bonds to Silicon Carbide and Diamonds." Miss Ludington, an electronic engineer, received her B.B.A. in Electronic Engineering and Management from Northeastern University in 1958. She joined AFCRL in 1951 as a member of the R.F. Components Laboratory, and has occupied her present position since 1957. She is a member of the American Vacuum Society. Mr. Phipps, a physical science technician, is a graduate of the Boston Museum School of Fine Arts. He is also a member of the American Vacuum Society and of the Scientific Glassblowers Society. Mr. Bloom, a general physical scientist, has a B.S. in Electrical Engineering from Northeastern University, and has also attended M.I.T. He has been with AFCRL since 1946, and is a member of the Institute of Electrical and Electronic Engineers, the American Association for the Advancement of Science, and the International Organization of Vacuum Science and Techniques.

Mr. Kenneth R. Cramer, a scientist with the Thermomechanics Research Laboratory, ARL since 1951, is conducting analytical investigations of various phenomena in flows of electrically conducting and nonconducting fluids. He is also engaged in analytical investigations of heat transfer. Previously, he had been concerned with free-convection heat transfer, the thermal problems of orbit-type space suits, and other research. Mr. Kramer has a B.M.E. from the University of Dayton (1951), and an M.S. from Ohio State University (1956). He has been a Registered Professional Engineer in Ohio since 1954, and has a great number of articles to his credit. In this issue of the Review, he writes on "Filaments in Electrical-Current Fields."